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Diels−Alder Additions of Benzynes within Helicene Skeletons

David Zhigang Wang,[†] Thomas J. Katz,[*,†]
James Golen,[‡] and Arnold L. Rheingold[‡]

Department of Chemistry, Columbia University,
New York, New York 10027, and Department of Chemistry
and Biochemistry, University of California, San Diego,
9500 Gilman Drive, La Jolla, California 92093

tjk1@columbia.edu

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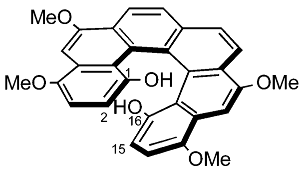
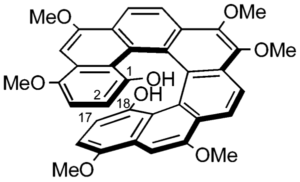
Abstract: Although the contortions required are unprecedented, the benzynes formed by the fluoride-induced elimination of TMSOTf from *o*-trimethylsilyl [6]- and [7]-helicenol triflates add to another ring of the helicenes rather than to an external furan molecule.

The combination of enol ethers of bis(aryl methyl ketones) and 1,4-benzoquinone makes it possible to prepare helicenebisquinones in multigram quantities and enantiopure form.[1] A subsequent $Na_2S_2O_4$ reduction/Russig−Laatsch methylation sequence applied to examples of such [6]- and [7]-helicenebisquinones leads to dihydroxyhelicenes **1** and **2**.[1d,2] In turn, electrophilic substitutions (bromination, acetylation, and formylation) and some rearrangement reactions have allowed these molecules to be elaborated regioselectively into derivatives that, notably, are functionalized at the inner, most sterically hindered positions (positions 1, 2, 15, 16 in **1** and 1, 2, 17, 18 in **2**).[3]



1



2

These discoveries suggest that the functionalized helicenes might be used to synthesize higher [*n*]-helicenes in which $n \geq 8$.[4] In pursuing this goal, we developed syntheses for **6** and **17**, the precursors of benzyne derivatives of two helicenes, and found that these undergo novel transformations in which one ring of a helicene adds to another. The products are bridged derivatives of coronene.

By silylating [7]-helicene **3**, which is easy to prepare in amounts greater than 10 g (by benzylating the inner hydroxyl groups of **2** and then brominating with NBS),[3] **4** was obtained in 92% yield (Scheme 1**)**. The benzyl groups were then removed quantitatively[5] and replaced by triflate groups in 91% yield. Fluoride ion was expected to eliminate the *o*-trimethylsilyl triflate functions from **6**, giving benzynes,[6] which, if the solvent contains furan, were expected to add to the furan molecules. However, this is not what happened when **6** was treated with Me_4NF in a 3:1 furan−MeCN solvent mixture. After acid hydrolysis, a 1:1 mixture of isomers **9** and **10** was obtained in 90% yield. Not surprisingly, a different precursor of the same benzyne (**13**, prepared from **12**[3]) when treated with phenyllithium also gave **9** and **10**, albeit in a lower yield (67%).

The presumed intermediate, **7**, probably a mixture of *endo* and *exo* isomers, was too unstable to isolate. Ketone **8**, formed from it by brief acid hydrolysis, was more stable. However, although it could not be isolated pure, the ketone function was recognizable both by its ^{13}C NMR (a peak at δ 202 ppm) and its IR absorption (at 1724 cm^{-1}), and after being combined with *t*-BuOK and $PhCH_2Br$, **8** gave the *C*-benzylated product **11** (in 83% yield). The structure of **11**, determined by *X*-ray diffraction analysis of a single crystal, implies that the structures of **8**, **9**, and **10** are those pictured. The latter two are obtained when **8** is hydrolyzed more extensively in acid. (Their masses were analyzed by mass spectrometry.)

Similarly (Scheme 2**)**, [6]-helicene **14**, prepared in high yield from **1**,[3] gave the double benzyne precursor **17**, which, after fluoride-induced 1, 2-elimination in furan and acid hydrolysis, gave **18**. The 1, 4-endo oxide moiety appears to be considerably more stable in this molecule than in **8**, for **18** does not rearrange to a phenol even after prolonged (2 h) exposure to aqueous HCl.

Since in these transformations the two generated benzynes behave differently−one adding internally to another helicene ring, the other externally to a furan

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[†] Columbia University.

[‡] University of California, San Diego.

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(2) Dreher, S. D.; Paruch, K.; Katz, T. J. *J. Org. Chem.* **2000**, *65*, 806.

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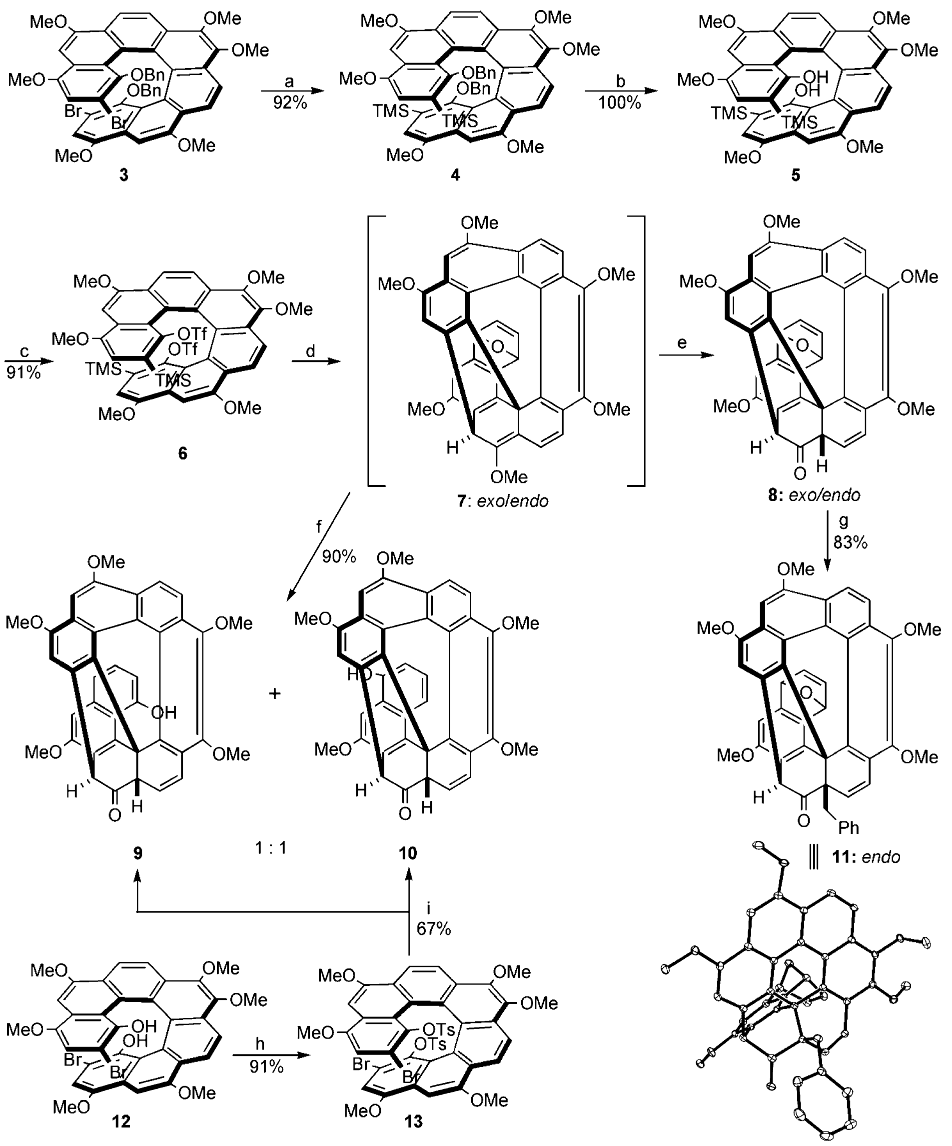
SCHEME 1[a]



[a] For clarity hydrogen atoms have been omitted from the drawing of the structure according to X-ray diffraction analysis, at the lower right. Reagents and conditions: (a) BuLi, TMSCl, Et_2O, −50 to 25 °C, 10 h; (b) 10% Pd/C, HCO_2NH_4, 1:1 THF−MeOH, 25 °C, 2 h; (c) BuLi, Tf_2O, −78 to 25 °C, 1 h; (d) Me_4NF, furan-MeCN (3:1), 0 °C, 2 h; (e) HCl in 1:1 MeOH−CH_2Cl_2, 5 min, 25 °C; (f) HCl in 1:1 MeOH−CH_2Cl_2, 15 min, 25 °C; (g) *endo* isomer, *t*-BuOK, THF, 30 min, then $PhCH_2Br$, 25 °C, 3 h; (h) NaH, THF, 30 min, then TsCl, 25 °C, 5 h; (i) PhLi, furan−THF (1:3), −78 to 25 °C, 4 h, then concd HCl, 25 °C, 30 min.

ring−experiments were carried out to see whether the former reaction can occur before the latter. Accordingly (Scheme 3), the precursor, **21**, of a monobenzyne was synthesized by monosilylating **3**. This was achieved by treating **3** with only limited amounts of BuLi before TMSCl was added and then debenzylating and triflating as before. This sequence gave **21** in 46% yield. Its exposure to fluoride in a 1:1 furan−acetonitrile mixture and then to methanolic HCl led only to **22**, implying that a benzyne function preferentially adds to the internal ring rather than to the external furan.

Unsaturated carbon substituents (carbocations,[7] vinyl groups,[8] carbenes,[9] and methylenes[10]) at 1-positions have previously been seen to add internally to another ring of helicenes (usually to the carbon atom 5 or 6 away) and, in the case of the vinyl substituent, in a Diels−Alder reaction, but in all of these cases the substituent's unsaturation was perpendicular to the plane of its attached benzene ring. Moreover, the unsaturated substituents have never been part of a ring, where their rotational flexibility would be constrained. The remarkable observation here is that the benzyne adds to another ring of its own skeleton, even though the former's reactive unsaturation is parallel to a benzene ring and the transformation must distort the structures much more

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(7) (a) Martin, R. H.; Jespers, J.; Defay, N. *Tetrahedron Lett.* **1975**, 1093. (b) Numan, H.; Wynberg, H. *Tetrahedron Lett.* **1975**, 1097. (c) Puls, C.; Stolle, A.; de Meijere, A. *Chem. Ber.* **1993**, *126*, 1635.

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(9) Jespers, J.; Defay, N.; Martin, R. H. *Tetrahedron* **1977**, *33*, 2141.

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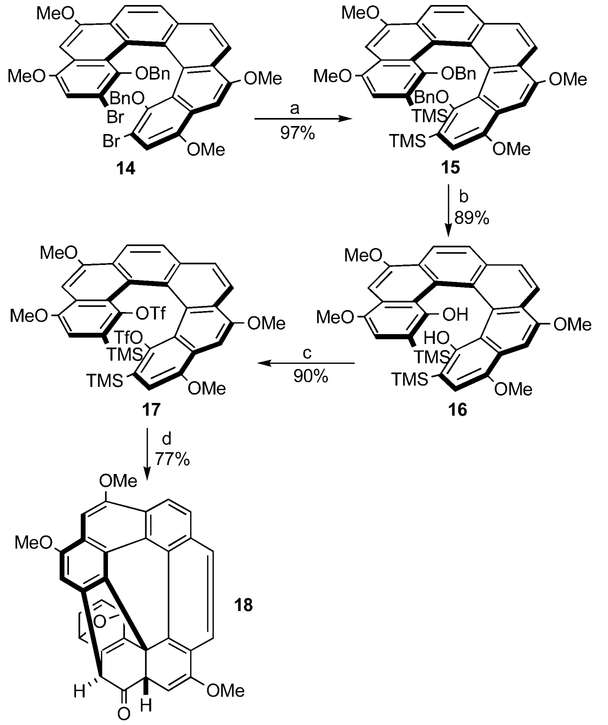
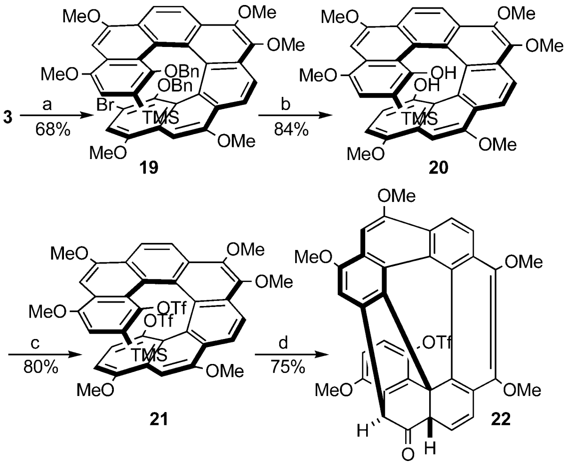
SCHEME 2[a]



[a] Reagents and conditions: (a) BuLi, Et_2O, −78 to 0 °C, 30 min, then TMSCl, 0 to 25 °C, overnight; (b) 10% Pd/C, HCO_2NH_4, 1:1 THF−MeOH, 25 °C, 4 h; (c) BuLi, Et_2O, −78 to 25 °C, 10 min, then Tf_2O, −78 to 25 °C, 2 h; (d) TBAF, furan, 0 to 25 °C, 2 h, then concd HCl, 25 °C, 30 min.

than in previous examples. It was in the hope that addition to the internal ring would be disfavored by this distortion while addition to the furan would be favored by its electron richness that the process described was studied as a way to increase by two the number of rings of a helicene.

SCHEME 3[a]



[a] Reagents and conditions: (a) BuLi, Et_2O, −78 to 25 °C, 30 min, then TMSCl, 0 to 25 °C, 6 h; (b) 10% Pd/C, HCO_2NH_4, 1:1 THF−MeOH, 25 °C, 7 h; (c) BuLi, Et_2O, −78 to 25 °C, 20 min, then Tf_2O, −78 to 25 °C, 1.5 h; (d) Me_4NF, furan−MeCN (1:1), 0 °C, 3 h; then MeOH saturated with HCl (g), CH_2Cl_2, 25 °C, 20 min.

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Supporting Information Available: Experimental details; X-ray diffraction data for **11**; and ^{1}H NMR, ^{13}C NMR, and IR spectra of compounds **4**−**6**, **9**−**11**, **13**, and **15**−**22**. This material is available free of charge via the Internet at http://pubs.acs.org.

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